HABITAT SELECTION BY SELECTED BREEDING PASSERINE BIRDS IN PINE-OAK FORESTS OF NORTHERN ARIZONA

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A Thesis

Submitted in Partial Fulfillment

of the Requirements for the Degree of

Master of Science in Forestry

Northern Arizona University

August, 1999

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ABSTRACT

HABITAT SELECTION BY SELECTED BREEDING PASSERINE BIRDS IN PINE-OAK FORESTS OF NORTHERN ARIZONA

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Forest treatments proposed to restore pre-settlement conditions for northern Arizona ponderosa pine (*Pinus ponderosa*) forests will dramatically alter forest structure by reducing densities of smaller diameter trees. Baseline information on habitat selection is needed to understand responses of passerine birds to these treatments. During the 1997 and 1998 breeding seasons, I examined foraging-habitat selection by 5 permanent resident species - hairy woodpeckers (*Picoides villosus*), mountain chickadees (*Poecile gambeli*), white-breasted nuthatches (*Sitta carolinensis*), pygmy nuthatches (*S. pygmaea*), and dark-eyed juncos (*Junco hyemalis*) - and 3 neotropical migrants, Virginia's warblers (*Vermivora virginiae*), plumbeus vireos (*Vireo plumbeus*), and western tanagers (*Piranga ludoviciana).* I measured and analyzed habitat selection at 2 scales, the foraging tree (third-order selection *sensu* Johnson 1980) and within a 0.04-ha plot centered on each foraging location (Johnson's second-order selection).

I analyzed microhabitat selection for all species with > 41 observations. I detected third-order selection by pygmy nuthatches and Virginia's warblers at Camp Navajo and by white-breasted nuthatches, dark-eyed juncos, and hairy woodpeckers at Mt. Trumbull. CART models indicated second-order selection by white-breasted nuthatches, pygmy nuthatches, Virginia's warblers, plumbeus vireos, and western tanagers at Camp Navajo

and by pygmy nuthatches, dark-eyed juncos, and plumbeus vireos at Mt. Trumbull. Ponderosa pines > 45.5 cm dbh and Gambel oaks (*Quercus gambelii*) > 30.5 cm dbh were selected by resident species, plumbeus vireos, and western tanagers, whereas Gambel oak densities of all size classes were selected by Virginia's warblers.

If individual oak trees >23.0 cm dbh and oak clumps with a crown area $\geq$139 m^2 are retained at Camp Navajo, I believe that the foraging habitat of the 8 focal bird species that I studied will not be significantly affected by proposed forest restoration treatments. Because the Mt.Trumbull thinning treatments will decrease tree densities more than treatments at Camp Navajo, abundance and reproductive productivity may decline for bird species that primarily use foliage as a foraging substrate. This productivity most likely depends on the impacts of restoration treatments to the arthropod community. In addition, despite efforts to protect some pine and oak trees and snags from fire, significant habitat components used for foraging and nesting will initially be lost. However, if restoration treatments do ultimately change the structure and function of these ponderosa pine ecosystems such that primary production increases and consequently enhances arthropod biomass, habitat quality may improve for these 8 passerine birds.

ACKNOWLEDGMENTS

I have many people to thank for their generous help and advice during the course of this research. I would like to start by thanking my committee members, Paul Beier, Bill Block, Carol Chambers, and Steve Rosenstock: Paul Beier, my major professor, for his willing and cheerful manner when answering the variety of questions I presented to him and for his seemingly tireless ability to conduct many tasks at once which is an inspiration; Bill Block for always "having a minute" when I asked for one; Carol Chambers for her practical approach to any problem; and Steve Rosenstock for his constant and persistent support throughout all aspects of this project which kept me going during tough times.

This project was funded in part by the U.S. Army National Guard. I am grateful to the many people at Camp Navajo who allowed me to conduct this research on their base. I owe special thanks to Sargent Don Hack for making this project possible through his cooperation. I also thank the BLM, the Native American Forestry Program, and Stanford University for additional funding and personnel.

I could not have collected all the data without the help from several people who assisted me in the field. I thank Carmen Austin, Debbie Brown, Laura Doll, Tammy Hinesley, Tricia Hurley, Vicki Lesh, Lisa Miller, Jennifer Monks, Dan Nance, Ben Saenz, Rebecca Wozniak, and Lisa Yellow-Eagle for their long days of work starting before sunrise.

I also thank Rick Miller for his part in initiating this project. Jeff Jenness was a great help in map making. And, thanks to Amy Waltz, Pete Fulé, and Doc Smith from the ecology lab at NAU for sharing information.

Finally, thanks to my parents for their support throughout my life that gives me strength to finish what I start and for teaching me the importance of knowledge.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Since Euro-American settlement (circa 1870), logging, livestock grazing, and fire suppression have altered the composition, structure and function of ponderosa pine (*Pinus ponderosa*) forests in the southwestern U.S. (Southwest) (Cooper 1960, White 1985, Covington and Moore 1994a). The effects of these land-use practices include dramatic changes in tree density and forest structure, diminished tree vigor, loss of herbaceous vegetation, "epidemic" outbreaks of insects and tree diseases, and increased size and frequency of stand-replacing crown fires (Cooper 1960, Covington and Moore 1994a, Covington and Moore 1994b, Kolb et al. 1994). Because of these changes, large-scale forest restoration treatments may soon occur in ponderosa pine forest in northern Arizona.

Forest restoration experiments have already been initiated in northern Arizona at 2 study sites, Camp Navajo and Mt. Trumbull. The Arizona Army National Guard, Camp Navajo, in cooperation with Northern Arizona University (NAU) researchers, is conducting a forest restoration experiment following the recommendations of Covington and Moore (1992). Restoration experiments initiated in 1996 at the Mt.Trumbull Resource Conservation Area (MTRCA) are a cooperative effort between NAU and the Bureau of Land Management (BLM). The idea behind these treatments is to restore the ponderosa pine ecosystem to a condition that existed before Euro-American settlers began altering the landscape; a condition to which this ecosystem evolved and can maintain.

These forest restoration treatments involve thinning most "post-settlement trees" (trees originating after 1870), followed by fuels manipulation (removal of heavy fuel build up around old-growth trees) and prescribed broadcast burning (initial fall burn

followed by spring burns every 4-7 years). Anticipated effects of these treatments are decreased overstory foliage volume, tree density, and down woody debris, and increased herbaceous vegetation and tree vigor (Covington and Moore 1992). Because these treatments are still in the experimental stages, effects on associated wildlife populations are unknown.

Habitat selection by birds depends on a combination of factors such as bird structural morphology, landscape features, habitat structure, foraging and nesting opportunities, edge area, microclimate, and the presence of other species and conspecifics (Hildén 1965, Cody 1985, Wiens 1992). While proximate factors such as landscape features and habitat structure have no biological significance to birds, they serve as reliable cues leading a bird to specific sites that provide ultimate factors (e.g., food, shelter) needed to survive (Hildén 1965).

Most small birds appear to select among habitats based on specific structural characteristics (Cody 1985). In ponderosa pine forests of northern Arizona, alterations in forest structure from land management practices such as logging have affected breeding bird communities (Overturf 1979; Balda 1975a,b; Szaro and Balda 1979a,b; Cunningham et al. 1980; Brawn and Balda 1988a,b; Rosenstock 1996). Restoration treatments also modify the forest structure and hence affect certain habitat elements used for foraging and nesting by passerine birds. While some information on breeding bird communities in northern Arizona exists, additional data on specific micro- and macrohabitats used for foraging and nesting are needed (Rosenstock 1996, Rich and Mehlhop 1997).

This study was part of a larger study to examine the effects of large-scale

restoration efforts on the passerine bird community. I studied selection of foraging habitat by 5 permanent resident species - hairy woodpeckers (*Picoides villosus*), mountain chickadees (*Poecile gambeli*), white-breasted nuthatches (*Sitta carolinensis*), pygmy nuthatches (*S. pygmaea*), and dark-eyed juncos (*Junco hyemalis*) - and 3 neotropical migrants, Virginia's warblers (*Vermivora virginiae*), plumbeus vireo (*Vireo plumbeus*), and western tanager (*Piranga ludoviciana*). I chose these 8 focal species because their foraging and nesting ecology (not part of this thesis) represented a variety of microhabitat conditions that may be affected by restoration. For example, the 3 neotropical migrants and the mountain chickadee are primarily foliage gleaners, hairy woodpeckers and nuthatches mainly bark glean, and juncos are primarily ground gleaners. Further, nuthatches, chickadees, and hairy woodpeckers are cavity nesters, western tanagers and plumbeous vireos build cup nests in the canopy, and juncos and Virginia's warblers are ground nesters. In addition, I found these 8 species in abundance during a 1996 pilot year, indicating I would have adequate sample sizes for statistical analysis. My objectives were to collect pre-treatment data for subsequent evaluations of restoration treatment effects on passerine bird communities, and to quantify foraging habitat selection. My research hypothesis was that each focal species nonrandomly selected foraging locations.

METHODS

STUDY AREAS

I collected data at 2 study sites, Camp Navajo and Mt. Trumbull Resource Conservation Area (MTRCA). Both study sites were divided into treatment and control areas based on proposed forest restoration treatment designs. Restoration treatments at

Camp Navajo will be conducted on 700 ha during 1999-2002, treating 80 - 200 ha per year. Treatments at Mt. Trumbull were initiated in 1996 and will continue through 2000.

Camp Navajo is located 16 km west of Flagstaff, Arizona (Fig. 1). The 800-ha bird study site (400 ha treatment and 400 ha control) is located along the western boundary of the facility. The bird treatment area overlays the proposed forest restoration treatment area, and the control area is approximately 1.5 ha south of the treatment area. The forest canopy is dominated by ponderosa pine and Gambel oak (*Quercus gambelii*). Alligator bark juniper (*Juniperus deppeana*) is scattered on more xeric sites. In addition, patches of New Mexican locust (*Robinia neomexicana*) occur throughout the study site. Topography at Camp Navajo consists of gently rolling hills with a large hill (Volunteer Mountain) between the control and treatment areas. Elevations range from 2,134 - 2,453 m. Soils are mainly of volcanic origin, but limestone and sandstone soils may be found at lower elevations (Soil Conservation Service 1970, in Fulé 1996). For more detailed information on climate and land-use see Fulé (1996).

The MTRCA lies on the Arizona Strip approximately 80 kilometers southwest of Fredonia, Arizona (Fig. 1). The surrounding landscape is predominately desert, with ponderosa pine forest restricted to about 2,000 hectares, mostly above 2,100 m on the slopes of Mt. Trumbull and Mt. Logan. The Mt.Trumbull area also was divided into treatment and control areas, both approximately 400 ha blocks.

Like Camp Navajo, the Mt. Trumbull forest canopy is dominated by ponderosa pine and Gambel oak. Alligator juniper, piñon pine (*Pinus edulis*) and patches of New Mexican locust and big sagebrush (*Artemesia tridentata*) are scattered throughout control and treatment sites. Mt. Trumbull has comparatively more pines > 30.5 cm dbh, pinyon

and juniper trees, and New Mexican locust and fewer oak trees than the Camp Navajo site.

FORAGING SURVEYS

With the help of several assistants that had at least 10 days of training on bird identification and observation techniques, I conducted foraging surveys on control and treatment areas at both study sites (Camp Navajo and Mt. Trumbull) during the 1997 and 1998 breeding seasons (June through early July). Surveys were performed along 12 randomly located belt transects (Hejl et al. 1990) 2700-3300 m long placed parallel to each other with center lines 220 m apart. Almost all foraging surveys were conducted between 0530 and 1300.

While conducting a foraging survey, an observer slowly walked along a transect searching for individuals of the focal species. Once a foraging bird was encountered, the observer made sure the bird was either searching or procuring food and waited approximately 5 seconds to avoid bias toward more visually conspicuous locations. On the 5th second, the observer recorded the bird species, sex (determined only for hairy woodpeckers, Virginia's warblers, and western tanagers), foraging activity, and presence of other birds. I combined foraging activities into 4 categories based on behaviors described by Ehrlich et al. (1988): ground glean, bark glean, foliage glean (foliage glean or hover and glean), and flycatch (hawk or swoop). The foraging location was marked with a numbered metal tag, and directions to the site were recorded for subsequent habitat measurements. Then the observer resumed searching for a foraging bird. To ensure independence of individual bird observations, I recorded data for only the first bird seen in a pair or flock, and observations of conspecifics were at least 10 minutes (Hejl et al.

1990) and 100 m apart within the same year.

HABITAT MEASUREMENTS

I measured habitat characteristics at 2 microhabitat scales (as defined by Block and Brennan 1993), the foraging tree (third-order selection *sensu* Johnson 1980) and within 20 x 20 m (0.04-ha) *Used Plots* centered on each foraging location (Johnson's second-order selection). Similarly, habitat availability was measured on 0.04-ha *Available Plots* (193 at Camp Navajo and 170 at Mt. Trumbull) located 300 m apart on north-south transect lines. Adjacent transects were 150 m apart and even-numbered transects had start points offset north or south so that no Available Plot was more than 150 m away from a Used Plot. I assumed that these Available Plots were indeed available to all focal species (Morrison et al. 1986).

When a foraging bird was observed in a tree or shrub (woody plants < 1.4 m high), the following measurements were recorded: foraging location (tree or shrub species), plant diameter at breast height (dbh), plant class (alive, declining or dead portion, or snag at a specific level of decay), foraging zone (understory or on ground, below crown, lower crown, mid crown, or upper crown), substrate (trunk, branch, foliage, log or ground), and, if the foraging observation was in a large ($\geq$ 38.0 cm) ponderosa pine, the distance to the nearest large ponderosa pine (to determine tree clumpiness). If the foraging observation was on the ground, only data on the 0.04-ha plot were collected.

In each 0.04-ha Used and Available Plot, we measured slope with a clinometer and aspect with a hand-held compass. We tallied trees and snags in 6 diameter classes corresponding to the U.S. Forest Service's Vegetation Structural Stages (VSS): < 2.5 cm dbh (VSS 1), 2.5-12.5 cm dbh (VSS 2) , 12.5-30.0 cm dbh (VSS 3), 30.5-45.0 cm dbh

(VSS 4), 45.5-61.0 cm dbh (VSS 5), > 61.0 cm dbh (VSS 6). We determined canopy closure by point intercept at 49 points, using a vertical projection scope (Rosenstock 1996) every 2 m around the perimeter of the plot and on a transect through the middle of the plot. In addition, we recorded the presence and area (length x width of the vertical projection of the crown within the plot and in toto) of each oak clump, and, for each of 4 randomly chosen large ($\geq$ 38.0 cm) ponderosa pines, the distance to the nearest large pine.

At each of the 49 points where we measured canopy, we used point intercepts to classify the *Understory* as woody debris (branches, stumps or logs), herbs (root crowns of grasses and forbs), shrubs (woody plants < 1.4 m high), litter, rock (> 3 cm at longest axis), and soil (including rocks < 3 cm). All logs (> 15 cm at midpoint and > 1 m long) within the plot also were recorded.

We quantified dwarf mistletoe infection in ponderosa pines, using Hawksworth's (1977) 6-point scale, in 10 trees representative of the size class distribution present within each plot. These 10 trees were chosen by selecting a random compass bearing and measuring the first tree in the appropriate size class. An overall mistletoe rating for each plot was calculated by averaging ratings of the 10 sampled trees.

STATISTICAL ANALYSIS

To achieve adequate sample sizes each year (Brennan and Morrison 1990), and because sexes were difficult to determine for 5 of the 8 bird species, I pooled sexes for all species. I also pooled across years to increase my sample size. Because foraging patterns may vary annually (Szaro et al. 1990), I used *t*-tests to test for differences between habitat values at Used Plots between years before I pooled data ($P < 0.10$).

At the third-order level (foraging site), I compared the proportion of tree species

and tree size classes used by a given species to the proportions present on Available Plots using a χ^2 test of homogeneity (Zar 1998). Chi-square values were considered only if the average expected observations within a category were ≥ 6 for $\alpha \leq 0.01$ level of significance (Roscoe and Byars 1971). Because I estimated availability, a χ^2 goodness of fit test was not appropriate (Thomas and Taylor 1990). Because the χ^2 test only determines differences between 2 distributions (used versus available trees in this case) but does not determine selection or avoidance of specific habitat components, I used Bonferroni confidenceintervals to ascertain direction of selection (Neu et al. 1974, Byers and Steinhurst 1984). Use of a given size class was considered significant if the proportion of the availability component fell outside the calculated 90% confidence interval around the observed proportion of use. Because the Bonferroni confidence interval cannot be determined when observed use is 0, I calculated the binomial probability of that event (no observations for that tree type or size class) occurring (Ott 1993). I protected against Type I errors with the Bonferroni procedure (Neter et al. 1990).

At the second-order level (0.04 ha plot around the foraging tree), I examined habitat selection at 2 scales, the patch scale and the study site scale. Second-order selection at the patch scale asks how foraging sites differ from nearby paired sites and is relevant to patch features such as tree clumpiness. I used paired samples *t*-tests to examine selection at the patch scale, pairing each Used Plot with the nearest Available Plot (never more than 150 m away). I reported values that were < 0.10 after a Bonferonni correction for multiple comparisons (Neter, Wasserman, and Kutner 1990).

Second-order selection at the study site scale asks the question "How does a foraging site differ from average conditions on the study area (Camp Navajo or Mt.

Trumbull)?" and is most relevant to questions about how an animal selects a home range within a broad vegetation type.

To examine second-order selection at the study site scale, I developed separate classification and regression trees (CART) models for each species and study site. CART is a nonparametric, stepwise procedure that builds a decision tree to classify data (in this case Used Plots versus Available Plots) using ≥ 1 binary splits that reflect values of independent variables (Steinberg and Colla 1995). Each split in the tree is tested against other possible splits using goodness of fit measures or significance tests. CART chooses the best model based on predictive accuracies and penalties applied to large (unparsimonious) trees. In setting the tradeoff between the predictive accuracy and parsimony, I chose the smallest tree within 1 standard error of the tree with the lowest cross-validation relative error rate. The cross-validation relative error rate was calculated using a 10-fold jackknife procedure (Steinberg and Colla 1995). In this procedure the data were divided into 10 equal subsets; 9 subsets were used as learning data and one as a test subset. The overall error rate was the average classification success from the 10 test subsets. To avoid confounding of predictor variables, if 2 or more predictor variables were correlated (Spearman $r \geq 0.700$), I chose the more biological meaningful variable to load into the CART model. I used the Spearman instead of Pearson's correlation coefficient because I wanted to test for linear and nonlinear-relationships. I only reported CART model results that had $> 50\%$ overall classification success. I used a binomial test to determine the probability that overall classification successes $\geq 55\%$ was significantly $> 50\%$. CART was not used to examine second-order selection at the patch scale because it cannot analyze paired samples. I chose CART over other predictive models (e.g.,

logistic regression, discriminant function analysis) because it identifies specific cut points of independent variables that best discriminate between Used and Available Plots. These cut points are easier to interpret for management purposes.

RESULTS

I obtained 29-86 foraging observations per species per study area (Tables 2 and 3). I found selection at the third-order level for all species with > 41 observations. I detected second-order selection at the patch scale by pygmy nuthatches and Virginia's warblers at Camp Navajo and by white-breasted nuthatches, dark-eyed juncos, and hairy woodpeckers at Mt. Trumbull. CART models indicated second-order selection (study-site scale) by white-breasted nuthatches, pygmy nuthatches, Virginia's warblers, plumbeus vireos, and western tanagers at Camp Navajo and by pygmy nuthatches, dark-eyed juncos, and plumbeus vireos at Mt. Trumbull. None of the habitat variables that differed between years appeared as significant characteristics for habitat selection (Table 1).

THIRD-ORDER SELECTION

All focal birds usually used live trees for foraging substrates (Table 4). Mountain chickadees foraged mainly in live ponderosa pines, but used all substrates available (except locust) to some extent. This species selected pines in VSS classes ≥ 4 (> 30.5 cm dbh) and large oaks (> 30.5 cm dbh) (Camp Navajo site only), and avoided pines in VSS classes 1 and 2 (<12.5 cm dbh) and small oaks (<12.5 cm dbh) at both study sites (Tables 5 and 6). When foraging on live trees, chickadees mainly foliage gleaned in the mid and upper crowns (Tables 7 and 8).

Pygmy nuthatches foliage and bark gleaned (Table 7) almost exclusively in

middle and upper crowns of live pines (Tables 4 and 8). Like mountain chickadees, they selected pines in VSS classes ≥ 4 and avoided pines in VSS classes 1 and 2 (Tables 5 and 6). White-breasted nuthatches used both live oaks and pines as foraging substrates (Table 4). They selected similar foraging locations as mountain chickadees (Tables 5, 6 and 8), although their primary foraging technique was bark gleaning (Table 7).

Although dark-eyed juncos mainly ground gleaned (Table 7), we did observe them foliage gleaning and, less often, bark gleaning in live pines and oaks (Tables 4 and 7). At Camp Navajo they selected against small-diameter oaks and selected for medium-diameter oaks (12.5-30.5 cm dbh) (Table 5).

Few Virginia's warblers were found at Mt. Trumbull. At the Camp Navajo site, almost all Virginia's warbler observations consisted of foliage gleaning in the upper crowns of Gambel oaks (Tables 4, 7, and 8). These warblers selected medium- and large-diameter oaks and avoided small-diameter oaks (Table 5).

Hairy woodpeckers primarily bark gleaned in the mid and upper crowns of live pines (Tables 4, 7, and 8). Although these woodpeckers often used VSS classes ≥ 4 pines and large-diameter oaks, the sample size was insufficient to meet χ^2 analysis requirements (Table 6).

Plumbeus vireos and western tanagers tended to use VSS classes 5 and 6 (> 45.5 cm dbh) pines and large oaks more than smaller diameter trees for foraging sites, although I only had adequate sample sizes for plumbeus vireos at Mt. Trumbull (Tables 5 and 6). I observed vireos primarily foliage gleaning mostly in the middle of the crown, whereas tanagers tended to foliage glean in the upper crown (Tables 7 and 8).

SECOND-ORDER SELECTION

Patch scale

Although I measured many habitat variables (Tables 2 and 3), ponderosa pine and Gambel oak density and size class were the only variables that appeared significant for foraging habitat selection. Compared to nearby paired Available Plots, white-breasted nuthatches at Mt. Trumbull and pygmy nuthatches at Camp Navajo foraged in plots with relatively high densities of VSS classes 5 and 6 pines (Table 9). Virginia's warblers at Camp Navajo selected sites with high densities of small (< 2.5 cm dbh) locust and oak trees of all sizes. At Mt. Trumbull, dark-eyed juncos selected areas with significantly fewer medium-sized (12.5-30.5 cm dbh) oak trees/ha, whereas hairy woodpeckers foraged in areas that had significantly more medium-sized oak trees/ha.

Study site scale

Habitat use by focal species was most often predicted from a single variable (6 of 8 models). CART models successfully discriminated Used from Available Plots for white-breasted nuthatch, pygmy nuthatch, Virginia's warbler, plumbeus vireo, western tanager at Camp Navajo and for pygmy nuthatch, dark-eyed junco and plumbeus vireo at Mt. Trumbull (Table 10 and Fig.s 2 and 3). Overall classification accuracies ranged from 55-79%. The CART model that had the lowest reported classification accuracy (55% for pygmy nuthatches at the Mt. Trumbull site) was significantly greater than 50% ($P = 0.01$) using a binomial test.

At Camp Navajo, both pygmy and white-breasted nuthatches were associated with plots that had >12.5 VSS class 5 and 6 pine trees/ha, and Virginia's warblers occupied plots with >263 medium-sized (12.5-30.5 cm dbh) oaks (Table 10). Pygmy nuthatches at

Mt. Trumbull were associated with plots that had <137.5 oak saplings (< 12.5 cm dbh)/ha which had a spacing of large (> 38 cm dbh) pines 6.75-14.75 m (Fig. 2). At Mt. Trumbull, Dark-eyed juncos were found most often in plots with large pines spaced > 6.25 m apart (Table 10).

I obtained similar models for plumbeus vireos and western tanagers at both study sites. Vireos selected areas with fewer (< 287.5 trees/ha) VSS class 1 and 2 pines at Mt. Trumbull and VSS 3 (12.5-30.0 cm dbh) pines (< 37.5 trees/ha) at Camp Navajo than expected. They also were associated with a relatively high total basal area (16.15 m^2/ha) at Mt. Trumbull (Table 10 and Fig. 3). Similarly, western tanagers occupied areas with < 37.5 VSS 3 pines/ha at Camp Navajo (Table 10). Although the CART model for tanagers at Mt. Trumbull had a poor overall classification accuracy (42%) because it poorly predicted Available Plots, results followed the same trend found at the Camp Navajo site (< 287.5 trees/ha small pines in used plots), correctly classifying 87% of Used Plots.

DISCUSSION

HABITAT SELECTION

I detected habitat selection at both second- and third-order levels of selection. Densities of large ponderosa pines and large Gambel oaks were the most important habitat components for permanent resident species, plumbeus vireos, and western tanagers, while oak densities of all size-classes were selected by Virginia's warblers. Each species exhibited consistent preferences for the same habitat components at all levels of selection. However, selection appeared strongest at the third-order selection (individual tree) and progressively weaker at second-order levels. This result may have been a result of my sampling design. In addition, because I pooled data across years to

achieve adequate sample sizes for χ^2 analysis, annual variation in foraging tree and substrate selection may have been masked.

Overall classification accuracies for CART models which measured second-order selection at the study-site scale ranged from 55-79%. Although I found that 55% was significantly more than 50%, correctly predicting the occurrence of a species in a certain habitat only 55% of the time is not that accurate in terms of management. Indeed, Hurley (1986) noted that because accuracy of predictive models are affected by stochastic events, detectability of species, and sampling error, managers prefer models with accuracy levels of 75-80%. The CART models for the three neotropical migrants (Virginia's warbler, plumbeous warbler, and western tanager) at Camp Navajo were the only models that achieved accuracy levels $\geq$ 75%. Although CART model results for permanent residents were consistent with third-order selection, classification accuracies were lower indicating that permanent residents tended to be more general in their habitat selection than neotropical migrants at a larger habitat scale.

At all habitat scales that I examined, pines > 45.5 cm dbh were selected by permanent resident species for foraging. White-breasted and pygmy nuthatches selected for this habitat feature at all habitat scales at one or both study sites. Mountain chickadees selected pines > 45.5 cm dbh at the third-order level, but not at the second-order level. Rosenstock (1996) found that pygmy nuthatches in northern Arizona were associated with stands in which pines > 61 cm dbh comprised 30-50% of basal area, whereas mountain chickadees and white-breasted nuthatches tended to be more opportunistic (*sensu* Rosenweig 1985), using habitat in their encountered proportions. Similarly, O'Brien (1990) noted that mountain chickadees and white-breasted nuthatches

just south of Mt. Trumbull were more general in their habitat use than pygmy nuthatches, responding to density of piñon pines, juniper and Gambel oak trees in addition to ponderosa pine density.

Spacing of pines ≥38.0 cm dbh, which is inversely related to large pine density, was a significant at the study site scale for dark-eyed juncos and pygmy nuthatches at the Mt. Trumbull study site. Dark-eyed juncos were more likely to forage in plots that had > 6.25 m spacing between large pines. Since this species is primarily a ground forager, an open forest that has a more developed herbaceous component and less pine needle ground cover may provide a greater abundance of arthropods. In other studies in ponderosa pine forests, juncos have occupied various stand conditions (Szaro and Balda 1979a, Siegel 1989, Rosenstock 1996), indicating that they are habitat generalists (*sensu* Rosenweig 1985). Similarly, at the Camp Navajo study site, juncos used habitat as it was available at the second-order level of habitat selection.

The variable that best differentiated Used and Available plots in the CART model for pygmy nuthatches at Mt. Trumbull split was large pine spacing at the second and third splits. According to the model, pygmy nuthatches were found in plots with < 137.5 oak saplings/ha and large pine spacing of 6.75-14.75 m apart. These results were consistent with Camp Navajo CART results which associated pygmy nuthatches with plots that had > 12.5 VSS 5 (45.5-61.0 cm dbh) and 6 (>61.0 cm dbh) pine trees/ha – a density consistent with a spacing of < 28 m between pines ≥ 38.0 cm dbh.

Plumbeus vireos and western tanagers also frequently used pines > 45.5 cm dbh at the third-order level. At the second-order level, both species selected lower densities of VSS classes 1 and 2 pines indicating that areas with some large pines rather than many

small ones was preferred. Szaro and Balda (1979a) found similar results in pine-oak forests in northern Arizona. They reported more plumbeus vireos in strip cut plots that had approximately 181 trees/ha and a basal area of 12.4 m^2/ha than on control plots that had 647 trees/ha and a basal area of 26.7 m^2/ha. Similarly, more tanager occupied silviculturally-thinned plots with approximately 236 trees/ha and a basal area of 15.0 m^2/ha than in control plots.

Although ultimately, insectivorous bird species may respond to available arthropod biomass (Brush and Stiles 1986), selection for large-diameter pines by foliage and bark gleaners may reflect proximate factors (*sensu* Hildén 1965) such as foliage volume and bark surface. I observed pygmy nuthatches and mountain chickadees foliage gleaning more than half the time, while I observed white-breasted nuthatches primarily bark gleaning. Larger diameter pines contribute more foliage volume and bole and branch surface area than do smaller diameter trees (Balda 1969, Biging and Wensel 1990, O'Brien 1990). Though I found no information on insect biomass in relation to canopy zone or size of ponderosa pine trees, Franzreb (1983) and Weikel and Hayes (1999) suggested that a more complex structure created from the increased surface area of the crown, bole and branches in conifers may provide higher insect densities. Similarly, Szaro and Balda (1979a) reported a positive correlation between foliage gleaners and ponderosa pine foliage volume. In addition, large-diameter conifers have deeper furrows in the bark than smaller trees of the same species (Jackson 1979, Mariani and Manuwal 1990). Adams and Morrison (1993) found that ponderosa pines which had rougher bark surfaces even at small diameter size classes had a higher abundance of insects than tree species with smoother surfaces.

At the third-order level, mountain chickadees, white-breasted nuthatches, dark-eyed juncos, and Virginia's warblers selected large- (> 30.5 cm dbh) and medium-diameter (12.5-30.5 cm dbh, except white-breasted nuthatches) oaks for foraging locations. Although I did detect significant use of oaks by plumbeus vireos and western tanagers, I did often observe both species foraging in the 2 larger size classes of oak.

As in pine trees, these insectivorous birds are most likely responding to arthropod biomass. Oaks tend to have more insect species than do coniferous trees (Southwood 1961, Saure and Kielhorn 1993), however, Brush and Stiles (1986) reported that insectivorous bird abundance in a mixed coniferous-deciduous forest in New Jersey peaked at times and places of highest arthropod biomass regardless of tree species present. They found that both bird and arthropod abundance in pine-dominated stands peaked from mid-June through July, whereas peak abundance in oak-dominated stands occurred from May to mid-June. Others (e.g., Hejl and Verner 1990, Sakai and Noon 1990) also found changes in foraging substrates (primarily plant species) used at different times during the breeding cycle. As I pooled across breeding cycle, I could not document differential use of pines and oaks throughout the breeding season. However, I observed several species of passerines including the focal species of this study foraging heavily on Gambel oak flower buds early in the breeding season.

Used Plots for hairy woodpeckers had higher densities of medium-sized oaks than paired Available Plots. These woodpeckers used Gambel oak trees for nesting substrates 25% of the time at Mt. Trumbull (P. Beier, Associate Professor, School of Forestry, Northern Arizona University, unpublished data), perhaps due to a shortage of pine snags (Table 4) that are preferred nest trees in ponderosa pine forests of Arizona and New

Mexico (Scott and Patton 1989). Similarly, Rosenstock (1998) found greater abundance of resident birds, including hairy woodpeckers, in ponderosa pine stands that had higher densities of Gambel oak.

At the second-order level, Virginia's warblers selected plots with higher densities of small and medium-sized oaks. Of the foraging observations where sex of Virginia's warblers was determined, 88% were males. Correspondingly, Rosenstock (1998) detected Virginia's warblers only in ponderosa pine forest stands that contained Gambel oak, and Fischer (1978) reported that Virginia's warbler territories in Coconino County, Arizona, were dominated by Gambel oak thickets. Fischer (1978) suggested that these warblers may actually be selecting the shrubby growth form rather than the actual plant species. In addition, Fischer and I observed Virginia's warblers nests in dense oak patches. Nest-site selection may affect foraging location as foraging parents would travel a limited from the nest to forage (i.e., Central Place Foraging *sensu* Orians and Pearson 1979).

POTENTIAL EFFECTS OF RESTORATION TREATMENTS

Thinning

Several forest restoration projects, leaving approximately 13-70 ponderosa pine trees/ha, ranging from approximately 5 - 40,000 ha are either underway or in the planning stages in northern Arizona and New Mexico (A. E. Waltz, Research Specialist and H. R. Smith, Program Coordinator, Ecology Lab, NAU, pers. commun.). Large pines were an important habitat component for mountain chickadees, white-breasted nuthatches, plumbeus vireos, and western tanagers on both study sites. At Camp Navajo, estimated post-treatment densities of pines > 51.0 cm dbh are approximately 20 trees/ha and no

oaks over 23.0 cm will be cut (Hack et al. 1998). Proposed and completed thinning treatments at Mt. Trumbull are more intensive and only 15 pines > 51.0 cm dbh/ha will be retained at this site.

Although restoration treatments will probably increase vigor of the remaining large trees, and this in turn may increase foliage volume per tree, overall stand foliage volume will decrease (Covington and Moore 1992). Severe decreases in foliage volume may negatively affect abundance and productivity of foliage gleaning species (mountain chickadees, pygmy nuthatches, solitary vireo, and western tanager) especially at the Mt. Trumbull site which has a more intensive thinning regime. Similarly, because white-breasted nuthatches selected patches with a high density (30.75 trees/ha) of large pines (higher than the average pre-treatment density), the thinning of pine trees over 45.5 cm dbh may have a negative impact on this species at Mt Trumbull. At the time of this writing, no pines over 40.5 cm and 56.0 cm dbh will be cut on Camp Navajo and Mt. Trumbull, respectively (P. Fulé, Senior Research Specialist, Ecology Lab, NAU, pers. commun.).

Gambel oak was also an important foraging substrate for focal species and is the only deciduous overstory tree (except for the occasional aspen stand) patchily distributed in ponderosa pine forests in northern Arizona (Kruse 1992). Gambel oak has 3 basic life forms: brushy thickets, characterized as a patch of oak stems < 4.5 m tall and < 7.5 cm dbh; clones of pole size stands, patches of oak stems > 4.5 m tall and > 7.5 cm dbh; and large individual trees (Kruse 1992). At both study sites, all 3 growth forms were present and used by focal bird species. With the exception of Virginia's warblers, none of the focal species selected the brushy thicket form.

Virginia's warblers depend on Gambel oak brush patches for foraging and nesting habitat. These patches, which had an average crown area of 139 m^2 in warbler Used Plots, were scattered throughout the forest, often occurring on dry slopes. According to the biological assessment conducted at Camp Navajo (Hack et al. 1998), this size class of Gambel oak would be thinned to 35 stems/ha. However, the current prescription is to thin oaks only after burning (H. R. Smith, Program Coordinator, Ecology Lab, NAU, pers. commun.).

On Mt. Trumbull, thinning treatments (437 ha) conducted in 1996 and 1997 retained approximately 58.0 oak trees/ha prior to burning (Ecological Restoration Program 1998 Annual Report). Specific size class density estimates for Gambel oak trees were not available. Assuming that no oak trees over 23 cm dbh will be cut and that some smaller diameter oaks will be retained as recruitment trees, mountain chickadees, dark-eyed juncos, white-breasted nuthatches probably would not be significantly affected by thinning of oak. Hairy woodpeckers used plots that had significantly more (65.75 vs. 23.78 stems/ha) medium-sized (12.5-30.5 cm dbh) oaks on average than paired availability plots. Significant reductions in oak density at the medium-diameter size classes may reduce foraging and nesting habitat for this species.

Prescribed fire

The other major component of forest restoration treatments described in this study is prescribed burning. Covington and Moore (1992) predict that reintroduction of periodic fires (every 4-7 years) in conjunction with thinning will increase herbaceous and shrub production and tree vigor. To protect "presettlement" pines, pine snags and, at some sites, large-diameter oaks, fuels are being raked 0.6 m from the bases of these stems. Gambel

oak is more susceptible to fire than ponderosa pine, and prescribed fires may consume many, perhaps most, oak thickets. With the reduction of these thickets, Virginia's warbler abundance will likely decrease initially, as this is their primary habitat in the ponderosa pine ecosystem. However, Gambel oak readily resprouts after fire (Clary and Tiedemann 1992), thus, prescribed burning may enhance Virginia's warbler habitat in the long-term depending on the time it takes a thicket at a given site to develop. If larger oak trees are not protected, other foliage gleaning species also may decrease in abundance. With the exception of pygmy nuthatches at Mt. Trumbull, all species at both study sites were observed foraging in oak trees 10-93% of the time.

In other studies, foliage-gleaning insectivores were more abundant in unburned sites in western mixed conifer forests than in stands that had experienced fires of severe intensity 7 years earlier (Bock and Lynch 1970) and moderate fires 3 years earlier (Taylor and Barmore 1980) and in partially logged or clearcut ponderosa pine forests in northern Arizona that had burned (intensity not mentioned) the previous year (Blake 1982). In addition, Taylor and Barmore (1980) reported fewer foliage gleaners in severely burned areas than in moderately burned areas 1-3 years after fires.

Other researchers reported mixed results for non-foliage gleaning guilds. For example, while breeding (Taylor and Barmore 1980) and nonbreeding (Blake 1982) hairy woodpeckers appeared to be attracted to wood boring insects in burned sites, nonbreeding white-breasted and pygmy nuthatches, which tend to search for insects in bark crevices, were more abundant on unburned sites (Blake 1982). Dark-eyed juncos were equally common in burned and unburned plots (Bock and Lynch 1970, Taylor and Barmore 1980).

If individual oak trees over 23.0 cm and some oak clumps with a crown area of approximately 139 m^2 or more are retained at Camp Navajo, I believe that the foraging habitat of the 8 focal bird species that I studied will not be significantly affected by proposed forest restoration treatments. Because Mt.Trumbull has a more rigorous thinning regime, species that depend on foliage for a foraging substrate may decline. In addition, it is likely that despite efforts to protect some trees and snags from fire, significant habitat components used for foraging and nesting will be destroyed. However, if restoration treatments do improve the structure and function of these ponderosa pine ecosystems over what currently exists, increases in primary production and consequently insect biomass may eventually improve habitat conditions for these passerine birds.

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Table 1. Habitat variables from Used Plots that differed (t-tests, $P < 0.10$) between years at Camp Navajo and Mt. Trumbull, Arizona.

Bird species	Habitat variable	Means (S.D.) 1997	Means (S.D.) 1998	P
Camp Navajo				
Mountain chickadee (n=86)	% herb cover[a]	0.24 (0.16)	0.31 (0.15)	0.036
	Distance (m) between large pines[b]	9.35 (5.41)	6.59 (3.97)	0.040
White-breasted nuthatch (n=77)	% herb cover[a]	0.26 (0.14)	0.33 (0.15)	0.025
	Oak snags > 30.5 cm dbh	0.17 (0.45)	0.000	0.032
Pygmy nuthatch (n=64)	% herb cover[a]	0.22 (0.12)	0.41 (0.17)	0.000
	% shrub cover[a]	0.02 (0.05)	0.08 (0.14)	0.023
Dark-eyed junco (n=78)	% shrub cover[a]	0.00 (0.01)	0.11 (0.17)	0.020
	Mistletoe rating	0.64 (0.77)	2.05 (1.28)	0.060
Mt. Trumbull				
Mountain chickadee (n=63)	Total basal area m^2/ha	64.20 (49.64)	90.50 (57.05)	0.059

[a] Variable was arcsine transformed.
[b] Pines $\geq$ 38.0 cm dbh

Table 2. Mean values for vegetation and physical characteristics on Available Plots and Used Plots (each 20x20-m) on the Camp Navajo study area during the 1997 and 1998 breeding seasons.

Characteristic	Available $n = 193$	MOCH[a] $n = 86$	WBNU $n = 77$	PYNU $n = 64$	DEJU $n = 78$	VIWA $n = 53$	PLVI $n = 29$	WETA $n = 35$
% ground cover								
Woody debris	4.12	4.32	3.04	4.19	4.18	3.01	3.77	2.88
Shrub	2.38	1.43	1.58	1.31	2.23	10.07	2.75	3.18
Grass or forb	11.98	10.13	10.49	12.59	12.04	7.52	17.32	12
Litter	61.74	66.9	68.14	65.53	61.39	61.9	63	69.46
Rock	9.06	7.74	8	7.87	8.48	9.67	4.41	5.43
Soil	10.72	9.48	8.75	8.51	11.68	7.83	8.75	7.05
Aspect (% of plots)								
316-45°	19.17	19.77	19.48	14.63	17.95	22.64	21.43	14.28
46-135°	8.29	9.30	15.58	18.75	10.26	7.55	3.57	11.43
136-225°	29.53	45.35	36.36	29.69	30.77	16.98	46.43	31.43
226-315°	48.44	25.58	29.27	37.50	39.73	50.94	28.57	37.14
% slope	13.67	10.59	10.43	10.55	11.22	18.06	10.63	13.55
% Canopy closure	44.42	46.40	43.37	46.83	43.42	52.10	44.73	46.98
Total logs	2.83	2.51	1.96	1.81	2.47	1.98	1.64	1.88
Ponderosa pines								
> 12.5 cm dbh	9.78	7.70	5.82	6.50	5.47	10.21	8.07	6.21
12.5-30.0 cm dbh	8.49	7.92	5.36	4.72	5.26	4.12	4.64	5.06
30.5–45.5 cm dbh	1.35	1.72	1.17	1.41	1.35	0.67	1.25	0.88
> 45.5 cm dbh	0.42	0.72	0.79	1.42	0.60	0.19	0.89	0.70
Gambel oaks								
< 12.5 cm dbh	10.37	9.94	6.49	7.63	9.99	20.00	7.39	6.45
12.5-30.5 cm dbh	5.47	4.60	5.22	4.17	5.71	15.19	6.36	6.73
>30.5 cm dbh	0.61	0.45	0.88	0.50	0.85	1.52	0.82	0.97
Locust stems								
< 2.5 cm dbh	3.10	1.19	1.48	0.97	4.33	34.54	3.54	3.58
2.5-12.5 cm dbh	0.13	0.55	0.00	0.16	0.89	2.37	0.00	0.00
Pine snags								
< 12.5 cm dbh	0.23	0.22	0.13	0.14	0.22	0.23	0.25	0.45
12.5-30.0 cm dbh	0.04	0.07	0.01	0.03	0.03	0.00	0.00	0.03
30.5-45.5 cm dbh	0.02	0.03	0.78	0.02	0.05	0.02	0.04	0.03
> 45.5 cm dbh	0.01	0.05	0.01	0.08	0.05	0.04	0.04	0.12
Oak snags								
0-12.5 cm dbh	2.76	2.22	1.49	1.81	1.82	3.69	2.50	1.18
12.5-30.5 cm dbh	0.30	0.33	0.14	0.19	0.23	0.60	0.18	0.21
>30.5 cm dbh	0.04	0.08	0.08	0.05	0.05	0.08	0.00	0.06
Pine BA (m^2/ha)	14.35	15.85	12.05	14.77	11.64	7.59	12.29	10.61
Total BA (m^2/ha)	21.53	21.98	19.12	20.33	19.49	26.39	20.38	19.20
Oak clump area (m^2 in 0.04-ha plot)	44.57	43.13	39.22	36.36	62.03	139.94	89.28	83.73
Mean large pine spacing (m)	9.79	7.73	10.91	8.91	11.04	17.32	8.86	9.81
Mean dwarf mistletoe rating	0.12	0.19	0.23	0.09	0.20	0.20	0.03	0.20

[a] MOCH = mountain chickadee, WBNU = white-breasted nuthatch, PYNU = pygmy nuthatch, DEJU = dark-eyed junco, VIWA = Virginia's warbler, PLVI = plumbeus vireo, WETA = western tanager.

Table 3. Mean values for vegetation and physical characteristics on Available Plots and Used Plots (each 20x20-m) on the Mt. Trumbull study area during the 1997 and 1998 breeding seasons.

Characteristic	Available $n = 170$	MOCH[a] $n = 63$	WBNU $n = 64$	PYNU $n = 36$	DEJU $n = 39$	HAWO $n = 41$	PLVI $n = 36$	WETA $n = 38$
% ground cover								
Woody debris	2.45	2.01	2.75	2.82	2.14	2.71	2.08	2.24
Shrub	4.27	4.46	2.45	3.26	7.8	3	2.83	4.72
Grass or forb	3.78	3.45	4.69	3.48	11.53	5.45	5.54	4.13
Litter	72.27	75.82	78.69	79.65	59.53	75.34	75.99	74.85
Rock	6.47	6.18	4.08	2.31	4.54	4.93	4.67	3.27
Soil	10.76	8.08	7.34	8.48	14.46	8.57	8.89	10.79
Aspect								
Flat	12.12	17.74	12.5	36.11	23.08	12.20	22.86	25.00
316-45°	32.72	24.19	26.56	38.89	25.64	26.83	31.43	11.11
46-135°	26.67	38.71	40.63	36.11	28.21	31.70	20.00	33.33
136-225°	18.18	11.29	14.06	11.11	17.95	26.83	22.86	22.22
226-315°	10.30	8.06	6.25	5.56	5.13	4.88	5.71	8.33
% slope	9.55	7.89	9.41	4.75	6.45	8.06	6.31	7.08
% Canopy closure	48.68	51.30	53.89	49.81	39.62	50.10	49.25	47.76
Logs	1.79	1.86	1.91	2.03	1.82	2.07	2.42	1.92
Ponderosa pines								
> 12.5 cm dbh	10.69	11.38	9.27	7.94	6.36	10.54	5.53	4.32
12.5-30.0 cm dbh	9.49	9.49	9.11	9.28	4.69	9.02	7.92	4.76
30.5 – 45.5 cm dbh	3.15	2.90	3.33	3.53	1.97	2.93	3.81	3.47
> 45.5 cm dbh	0.82	1.54	1.23	1.36	0.72	1.29	1.19	1.16
Oaks								
< 12.5 cm dbh	3.65	1.87	4.13	0.56	2.33	3.61	2.61	2.87
12.5-30.5 cm dbh	2.24	2.46	3.02	0.83	3.62	2.63	2.86	2.46
>30.5 cm dbh	0.06	0.11	0.09	0.11	0.26	0.22	0.39	0.24
Locust stems								
< 2.5 cm dbh	1.81	1.54	0.89	1.06	0.82	0.90	0.44	0.79
2.5-12.5 cm dbh	.52	.17	0.13	0.00	0.05	0.00	0.19	0.29
Ponderosa pine snags								
<12.5 cm dbh	0.52	0.49	0.25	0.28	0.03	0.59	0.03	0.05
12.5-30.0 cm dbh	0.08	0.11	0.11	0.00	0.05	0.10	0.00	0.03
30.5-45.5 cmdbh	0.03	0.11	0.02	0.03	0.03	2.93	0.00	0.03
> 45.5 cm dbh	0.01	0.05	0.08	0.03	0.13	1.29	0.00	0.00
Oak snags								
0-12.5 cm dbh	1.99	1.16	1.23	0.69	0.77	2.00	1.33	1.08
12.5-30.5 cm dbh	0.72	0.65	0.77	0.22	0.49	0.61	0.69	0.16
>30.5 cm dbh	0.02	0.02	0.06	0.00	0.00	0.02	0.00	0.00
Pine BA (m^2/ha)	13.52	15.87	15.57	16.40	9.27	14.81	16.18	14.57
Total BA (m^2/ha)	16.20	18.51	18.95	16.96	13.28	18.01	19.83	17.96
Oak clump area (m^2 in 0.04-ha plot)	26.77	15.50	23.95	5.04	38.72	35.38	16.36	22.86
Mean large pine spacing (m)	12.42	11.97	11.51	11.48	6.99	14.58	13.52	13.95

[a] Abbreviations are same as on Table 2.

Table 4. Percent use of 6 different substrates used by 5 permanent resident and 3 neotropical migrants during the breeding seasons of 1997 and 1998 in ponderosa pine forests of northern Arizona compared to trees available on each study area. "+"indicates selection for and "-" indicates selection against that diameter class, based on the 90% Bonferroni confidence interval for the proportion used not overlapping the available proportion. (Note: Ground observations are listed here for reference, but were excluded from χ^2 analyses).

Study site and bird species	Ground	Live pine[d]	Pine snag	Live oak[e]	Oak snag	Live piñon and juniper[f]
Camp Navajo						
Mountain chickadee ($n = 87$)[b]	2	69 +	1	28 -	0 -	0
White-breasted nuthatch ($n = 78$)[b]	1	63 +	4	30 -	2 -	0
Pygmy nuthatch ($n = 66$)[b]	0	85 +	3	12 -	0 -	0
Dark-eyed junco ($n = 82$)[c]	46	21	0	33	0	1
Virginia's warbler ($n = 54$)[b]	2	5 -	0 -	93 +	0 -	0 -
Plumbeus vireo ($n = 29$)[c]	0	69	0	31	0	0
Western tanager ($n = 35$)[c]	0	51	3	46	0	0
Available[a]		44	1	46	7	2
Mt. Trumbull						
Mountain chickadee ($n = 63$)[c]	10	71	0	6	2	11
White-breasted nuthatch ($n = 64$)[c]	6	69	1	16	3	5
Pygmy nuthatch ($n = 35$)[b]	0	100 +	0	0 -	0	0 -
Dark-eyed junco ($n = 39$)[c]	80	10	0	10	0	0
Hairy woodpecker ($n = 42$)[b]	3	51	7	29	3	7 -
Plumbeus vireo ($n = 37$)[c]	0	73	5	11	0	8
Western tanager ($n = 39$)[c]	26	59	0	15	0	0
Available		58	1	17	6	17

[a] Percentage of 6864 trees on 193 Available Plots at Camp Navajo, or 6153 trees on 170 Available Plots at Mt. Trumbull.

[b] Overall χ^2 tests for homogeneity between used and available trees were significant at $P < 0.001$.

[c] Overall χ^2 tests for homogeneity between used and available trees were not significant; no further tests conducted.

[d] Pine = *Pinus ponderosa*

[e] Oak = *Quercus gambelii*

[f] piñon = *Pinus edulis*, juniper = *Juniperus deppeana*,

Table 6. Proportion of ponderosa pine and Gambel oak size classes selected by 6 passerine birds at Mt. Trumbull, Arizona during breeding seasons of 1997 and 1998 compared to the size distribution of live pines and oaks available. All omnibus Chi-squared tests for homogeneity between used and available diameter distributions were significant at $P < 0.0005$ for each bird and tree species except where sample sizes were insufficient. "+"indicates selection for and "-" indicates selection against that diameter class, based on the 90% Bonferroni confidence interval for the proportion used not overlapping the available proportion.

Tree species and dbh class (cm)	Available proportion	Proportion used by [a] MOCH	WBNU	PYNU	HAWO	PLVI	WETA
Ponderosa pine							
< 12.5	0.44	0.02 -	0.02 -	0.00 -	0.00 [b]	0.04 -	0.09 [b]
12.5-30.0	0.39	0.37	0.34	0.29	0.19 [b]	0.40	0.43 [b]
30.5-45.5	0.13	0.28	0.26	0.34 +	0.24 [b]	0.40 +	0.13 [b]
> 45.5	0.04	0.33 +	0.37 +	0.37 +	0.57 [b]	0.20 +	0.35 [b]
Gambel oak							
< 12.5	0.61	0.09 [b]	0.20 [b]	0.00	0.17 [b]	0.25 [b]	0.00 [b]
12.5-30.5	0.38	0.64 [b]	0.60 [b]	0.00	0.50 [b]	0.50 [b]	0.67 [b]
> 30.5	0.01	0.27 [b]	0.20 [b]	0.00	0.13 [b]	0.25 [b]	0.33 [b]

[a] MOCH = mountain chickadees (n = 43 pines, 10 oaks), WBNU = white-breasted nuthatches (n = 35 pines, 10 oaks) , PYNU = pygmy nuthatches (n = 35 pines, 0 oaks), HAWO = hairy woodpeckers (n = 21 pines, 12 oaks), PLVI = plumbeus vireos (n = 29 pines, 4 oaks), and WETA = western tanagers (n = 23 pines, 6 oaks)

[b] Insufficient sample size (average expected observations over all categories ≥ 6 for the 0.01 level of significance) for χ^2 analysis.

Table 7. Foraging behaviors of 8 passerine birds at Camp Navajo and Mt. Trumbull, Arizona during the breeding seasons of 1997 and 1998.

Study site and bird species	Foraging behavior used (%)			
	Ground glean	Bark glean	Foliage glean	Flycatch
Camp Navajo				
Mountain chickadee (n = 87)	2	17	81	0
White-breasted nuthatch (n = 78)	2	90	8	0
Pygmy nuthatch (n = 66)	1	42	57	0
Dark-eyed junco (n = 82)	48	14	38	0
Virginia's warbler (n = 54)	2	4	93	1
Plumbeus vireo (n = 29)	0	31	62	7
Western tanager (n = 35)	0	14	83	3
Mt. Trumbull				
Mountain chickadee (n = 63)	10	35	55	0
White-breasted nuthatch (n = 64)	1	93	6	0
Pygmy nuthatch (n = 35)	0	32	68	0
Dark-eyed junco (n = 39)	80	0	20	0
Hairy woodpecker (n = 42)	3	94	3	0
Plumbeus vireo (n = 37)	0	19	76	5
Western tanager (n = 39)	26	5	49	20

Table 8. Foraging zones used by 8 passerine birds at Camp Navajo and Mt. Trumbull, Arizona during the breeding seasons of 1997 and 1998.

Study site and bird species	Foraging zone used (%)				
	Understory	Below crown	Lower crown	Mid crown	Upper crown
Camp Navajo					
Mountain chickadee (n = 87)	2	0	13	48	37
White-breasted nuthatch (n = 78)	2	5	19	39	35
Pygmy nuthatch (n = 66)	1	1	6	39	53
Dark-eyed junco (n = 82)	45	0	15	25	15
Virginia's warbler (n = 54)	2	0	8	14	76
Plumbeus vireo (n = 29)	0	3	10	52	35
Western tanager (n = 35)	0	0	12	31	57
Mt. Trumbull					
Mountain chickadee (n = 63)	10	0	28	29	33
White-breasted nuthatch (n = 64)	6	13	28	36	17
Pygmy nuthatch (n = 35)	0	3	6	37	54
Dark-eyed junco (n = 39)	77	0	13	10	0
Hairy woodpecker (n = 42)	3	7	7	45	38
Plumbeus vireo (n = 37)	0	0	32	49	19
Western tanager (n = 39)	28	8	8	28	28

Table 9. Habitat variables that differed significantly (paired samples *t*-test, $P < 0.10$ after a Bonferroni correction) between Used and Available Plots at Camp Navajo and Mt. Trumbull, Arizona during the breeding seasons of 1997 and 1998.

Study site and species	Habitat variable (cm dbh)	Used Mean (std. dev.) (trees/ha)	Available Mean (std. dev.) (trees/ha)	*P*
Camp Navajo				
Pygmy Nuthatch ($n = 64$)	Ponderosa pines > 45.5	35.55 (33.88)	19.53 (29.38)	0.012
Virginia's warbler ($n = 53$)	Gambel oaks < 12.5	500.00 (549.00)	291.18 (486.50)	0.072
	Gambel oaks 12.5-30.5	379.75 (292.50)	179.75 (217.50)	< 0.010
	New Mexican locust < 2.5	863.50 (1583.25)	291.18(587.75)	0.024
Mt. Trumbull				
White-breasted nuthatch ($n = 64$)	Ponderosa pines > 45.5	30.75 (38.25)	15.63 (21.60)	0.039
Dark-eyed junco ($n = 39$)	Gambel oaks 12.5-30.5	117.25 (155.00)	248.08 (273.95)	0.070
Hairy woodpecker ($n = 41$)	Gambel oaks 12.5-30.5	65.75 (100.50)	23.78 (52.73)	0.065

Table 10. Habitat variable associations chosen by classification tree models for 6 passerine birds during the breeding seasons of 1997 and 1998, Camp Navajo and Mt. Trumbull, Arizona.

Study site and bird species	Habitat variable	Cut point values[a]		Overall classification accuracies[b]
		Used plots	Available plots[c]	
Camp Navajo				
White-breasted nuthatch (n=77)	Pines > 45.5 cm dbh	> 12.5 trees/ha (.69)	< 12.5 trees/ha (.63)	69%
Pygmy nuthatch (n=64)	Pines > 45.5 cm dbh	> 12.5 trees/ha (.73)	< 12.5 trees/ha (.70)	73%
Virginia's warbler (n=52)	Oaks 12.5-30.5 cm dbh	> 262.5 trees/ha (.80)	< 262.5 trees/ha (.69)	75%
Plumbeous vireo (n = 28)	Pines 12.5-30.0 cm dbh	< 37.5 trees/ha (.78)	> 37.5 trees/ha (.68)	79%
Western tanager (n = 33)	Pines 12.5-30.0 cm dbh	< 37.5 trees/ha (.78)	> 37.5 trees/ha (.68)	79%
Mt. Trumbull				
Dark-eyed junco (n = 39)	Pines ≥ 38.0 spacing	> 6.25 m apart (.65)	< 6.25 m apart (.75)	74%

[a] Values in parentheses represent proportion of observations correctly assigned to each outcome.
[b] Determined by jacknife cross-validation procedure.
[c] n = 193 Available Plots Camp Navajo and n = 170 for Mt. Trumbull.

Figure 1. Map of Mt. Trumbull and Camp Navajo study areas.

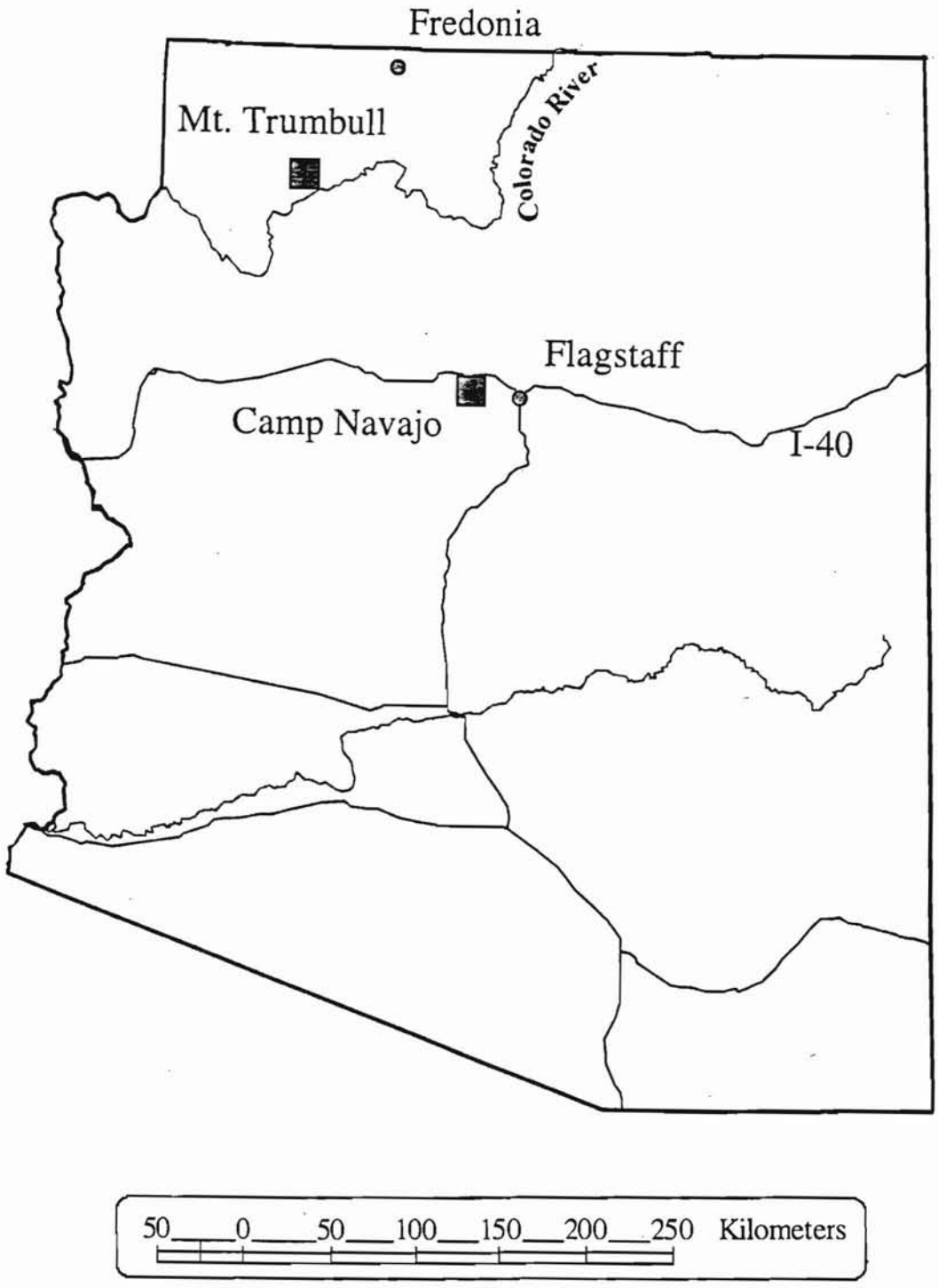

Fredonia
Mt. Trumbull
Colorado River
Flagstaff
Camp Navajo
I-40
50 0 50 100 150 200 250 Kilometers

Figure 2. Classification tree model of macrohabitat selection by pygmy nuthatches (n=36) during breeding seasons of 1997 and 1998 in a pine-oak forest, Mt. Trumbull, Arizona. The overall classification accuracy was 55%. Values in parentheses represent proportion of observations correctly assigned to each outcome.

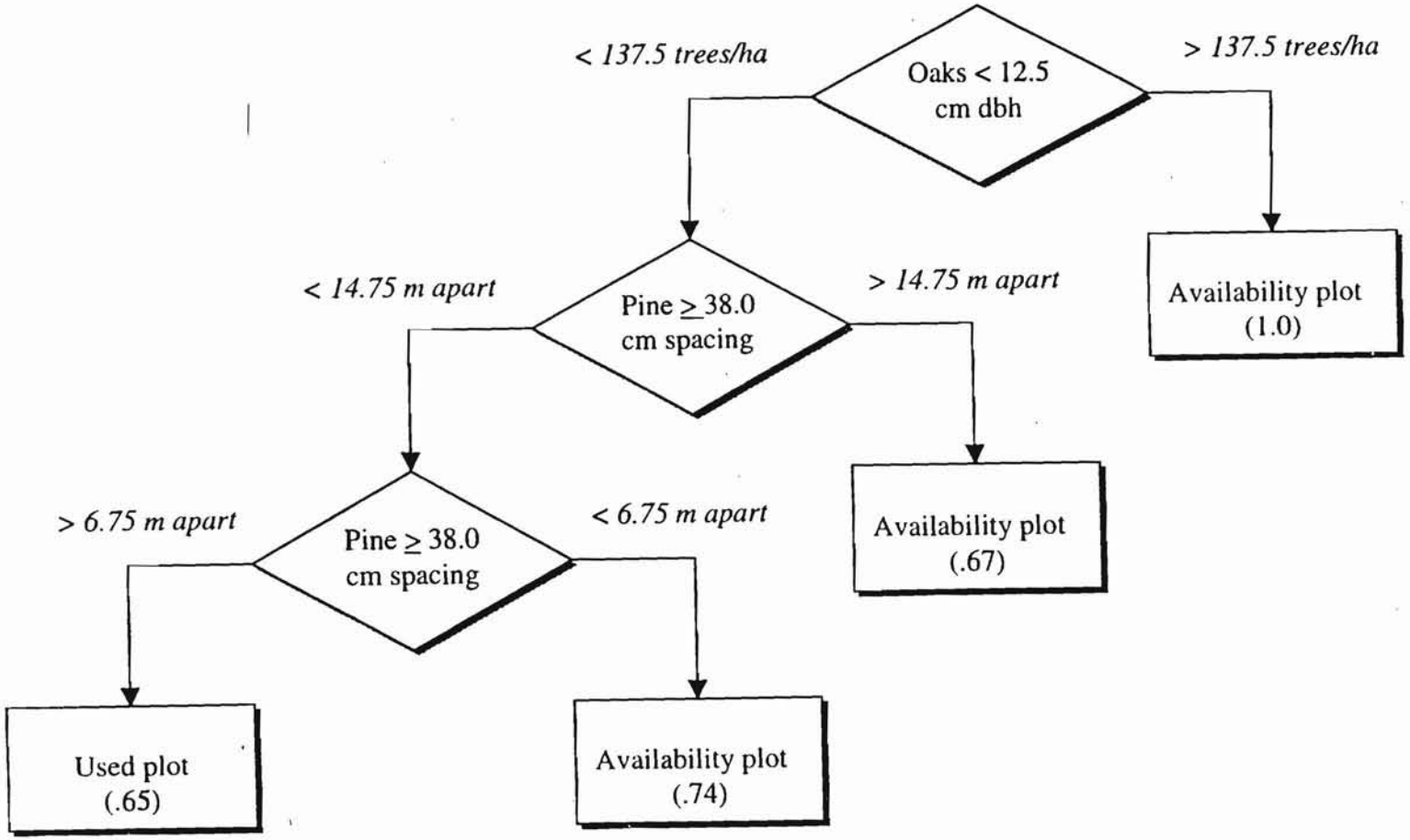
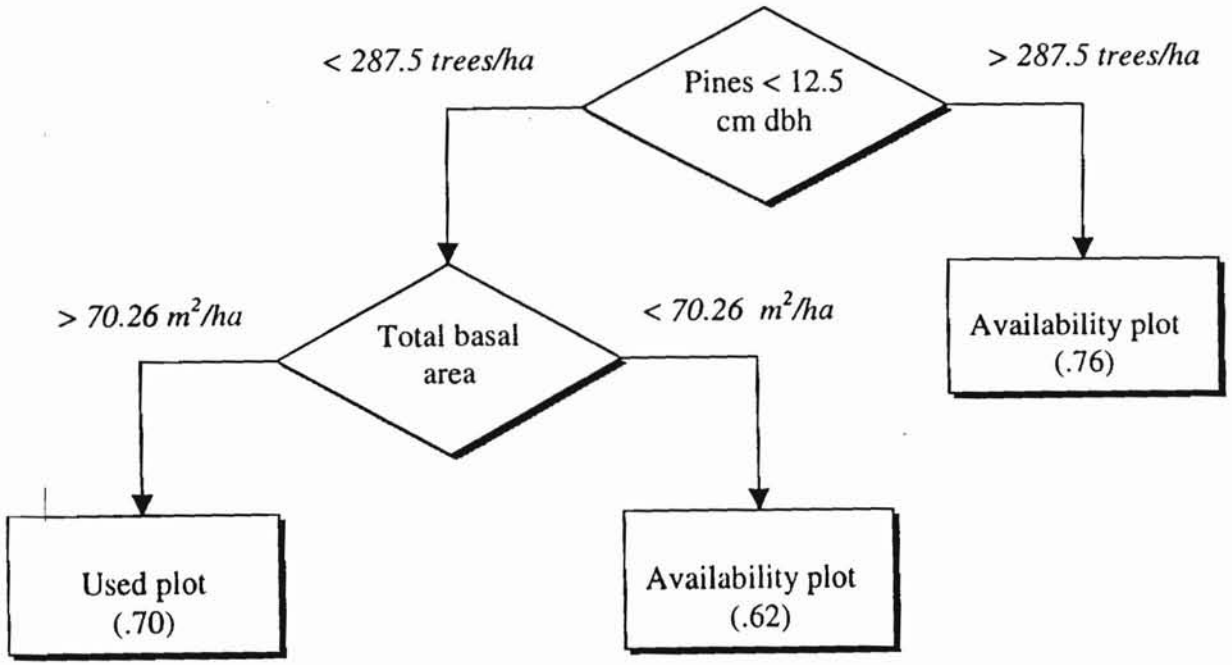

Oaks < 12.5 cm dbh
< 137.5 trees/ha
> 137.5 trees/ha
Availability plot (1.0)
Pine ≥ 38.0 cm spacing
< 14.75 m apart
> 14.75 m apart
Availability plot (.67)
Pine ≥ 38.0 cm spacing
> 6.75 m apart
< 6.75 m apart
Used plot (.65)
Availability plot (.74)

Figure 3. Classification tree model of macrohabitat selection by plumbeus vireos (n=36) during breeding seasons of 1997 and 1998 in a pine-oak forest, Mt. Trumbull, Arizona. The overall classification accuracy was 61%. Values in parentheses represent proportion of observations correctly assigned to each outcome.


< 287.5 trees/ha
Pines < 12.5 cm dbh
> 287.5 trees/ha
> 70.26 m²/ha
Total basal area
< 70.26 m²/ha
Availability plot (.76)
Used plot (.70)
Availability plot (.62)